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Maintenance Design of The Main Engine Support Systems on KMP. Kormomolin Under System Dynamics Scheme

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Abstract

The operational activities of the ship's main engine support system elevated the possibility of failure. The main engine support system at KMP. Cormomolin, which belongs to PT. ASDP Indonesia Ferry (Persero), is extremely crucial to the ship's operation. Once the ship is not sailing, maintenance and repair can be handled. The component evaluation engine can be employed to accurately estimate inadequacies in the main support system. Failure Mode Effect and Critical Analysis (FMECA) identifies the root cause of critical component failures such as filters in the fuel system and cooler and sea chest filters in the cooling system. This study generates maintenance recommendations for the main engine support system for five years, including: fuel oil filter maintenance intervals every 151 hours at a cost of IDR 14,169,072, cooler maintenance intervals every 2481 hours at a cost of IDR 16,313,508, and sea chest filter maintenance intervals every 722 hours at a cost of IDR 11,167,152. For the fuel system, the cost care percentage is 81%, and for the cooling system, it is 46% after 5 years.

Keywords: FMECA; Main engine support system; Maintenance; System dynamic

1. Introduction

PT. ASDP Indonesia Ferry (Persero) is an Indonesian State-Owned Enterprise (BUMN) that operates in the maritime industry. There are 30 branches throughout Indonesia. KMP. Kormomolin Vessel, which is located at the PT. ASDP Selayar branch, is one of the ships of PT. ASDP Indonesia Ferry that is the subject of this investigation. According to the results of a field survey as well as information obtained from various social media, KMP. Kormomolin suffered damage to the ship's main engine support system as many as 123 times between 2019 and 2021, whether the damage caused the engine to stop temporarily or the engine could not be started, resulting in the ship being unable to sail. The company's primary engine support system maintenance costs are IDR 125,675,300. PT.ASDP's maintenance management is a Breakdown Maintenance, which means that maintenance is performed when a component is damaged or no longer functions. This system does not employ a planned and scheduled maintenance system with component maintenance intervals, necessitating a significant financial investment.

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Fig.1. Actual View of KMP. Kormomolin Vessel

Ships continue to operate necessitate the company performing major maintenance on the components that help the main engine run more efficiently [1]. This is because if one of its components is damaged, the main motor will definitely have problems and will be unable to function properly. Because of the significance of each support system's role and function, proper maintenance management is require. Maintenance management can take the form of maintenance schedules and an analysis of the system's care and conditions after it has been treated [2]. This analysis is critical for predicting how the system will behave in the future, as well as the effects of the maintenance and operational policies that have been implemented. The most important relationship is the relationship between optimum maintenance costs and good system uptime, so that the ship can operate and generate optimum revenue [3]. Anticipating component failure in the main engine support system can be accomplished through reliability analysis or evaluation [4,5]. With system dynamics modeling [6,7,8,9], the implementation is completed by identifying how the system can fail and the consequences of the event based on the ship's operational schedule. The analysis performed can help to improve understanding of the operation and behavior of the support system. The analysis results can be used to determine the best maintenance schedule for each component that has failed operations, allowing for preventive and corrective maintenance to be performed to minimizing damage. This reliability assessment will be carried out through a qualitative (experience) and quantitative (calculation) analysis of the system. The aim of this study is to evaluate which critical components affect the KMP Kormomolin support system to break, to improve scheduled maintenance time, and to improve reliability on the main engine support system. As such, with this analysis, it is hoped that the main motor support system installed on the ship has good uptime and that the resulting optimum maintenance schedule can provide input to the operator so that maintenance costs can be minimized by operating the system properly and in accordance with procedures, so that the ship can sail on time and provide reasonable income to the company.

2. Materials and Methods

In general, the ship's main engine requires a support system in order to operate properly and without significant disruptions, and each unit of engine parts must receive optimal maintenance. The fuel and cooling systems on the main engine will be examined as supporting systems. Firstly, the fuel system serves as a support system for a critical main motor. Fuel supply, purification, transfer, and exhaust piping systems are all part of the fuel system. The fuel system is a system that transports fuel from the bunker to the service tank and then to the main engine or auxiliary engine. Depending on

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the type of engine and engine size, the fuel used on the ship may be Heavy Fuel Oil (HFO), Marine Diesel Oil (MDO), or ordinary diesel [10]. The complete picture is in Figure 1.Moreover, the cooling system is a system that is designed to keep the engine temperature at a specific level so that the diesel engine can run for an extended period of time, as depicted in Figure 2.Diesel engines generate heat at high temperatures; this cooling system is made up of several constituent components, the primary function of which is to cool the engine block; in addition to cooling the engine block, the cooling system also cools lubricants, water scavanges, and water jackets [11].

The first step in modeling system dynamics on the ship's main engine support system is to collect data, both primary and secondary data, and then use the PowerSim software to model system dynamics based on the data obtained. The fuel system and cooling system were used in the simulation and analysis of system dynamics and FMECA (Failure Mode Effect and Critical Analysis), see Figure 2 and Figure 3. The data was collected by going directly to the location of the case study, namely PT. ASDP Indonesia Ferry (Persero). Primary and secondary data were accumulated. At the primary data collection stage, interviews and secondary data sourced from the relevant literature were used. The following details are required in Table 1.

Table 1. Specifications of KMP. Kormomolin Vessel General Informations

Owner	PT. ASDP Indonesia Ferry
Ship name	KMP. Kromomoli
Flag	Indonesia
Production year	1997
Tracks	Bira-Pamatata
Ingredients	Steel
Ship Type	*Ro-Ro Passenger*
Classification	BKI 8957986
IMO Number	
Main Dimensions	
Length (LOA / LBP)	46.6 / 40.6 meter
Height	4 meter
Draft	2.15 meter
Gross Tonnage (GT)	884
Main Machines	
Brand	Yanmar
Type	4 *Cylinder Single Acting Vee*
Model	8 LAAM – UTE
Machine number	P/0393 S/0394
Bore & Stroke	148 x 165 mm
Production year	10th October 1998
Order Numbers	
Engine Power: 670 PK x 2	R8 – P290 A
Starter System	*Electric Starter Accu*
Firing Orders	R1 – L1 – R4 – R2 – L2 – R3 – L3 – L4
Capacity	80 liters x 2

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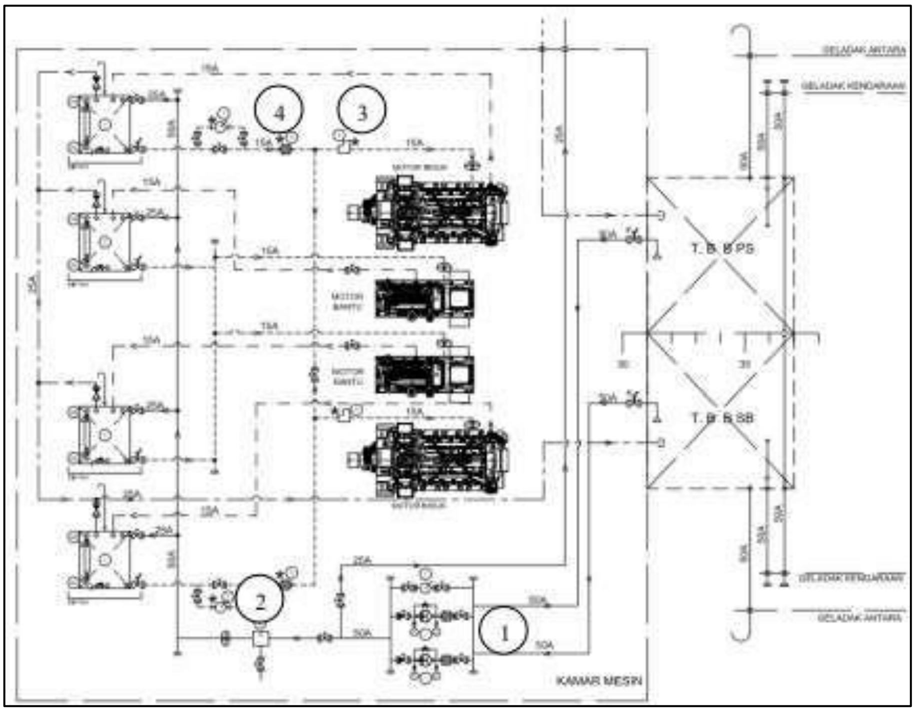

Fig.2. Fuel System of KMP. Kormomolin Vessel

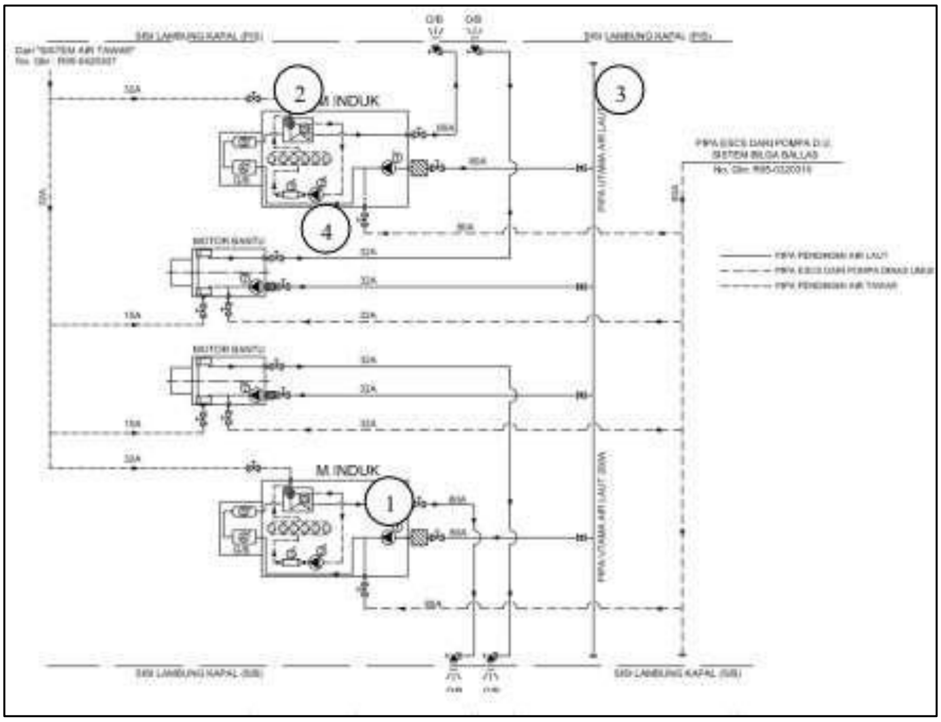

Fig.3. Cooling System of KMP. Kormomolin Vessel

3. Results and Discussion

3.1 FMECA Analysis

FMEA is a detailed functional failure analysis that allows for changes to add and remove components. The analytical process begins with the functional failure of each subsystem [12]. Additionally, the relationship between functional failures and equipment on the matrix are identified. Failure modes are discussed through interviews with sources associated with the primary engine support systems. The term failure mode is applied in this analysis based on OREDA's list of failure modes [13]. FMEA is divided into several stages, including failure analysis (product defects). At this early stage, the points of failure and those that cause failure are identified. This FMEA analysis identifies several causes of failure of the main engine support system. To begin, some components can be repaired by replacement, whereas others

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can only be repaired by maintenance or cleaning. The failure of a component can also have no effect on the sub-system. As a result, even if a component fails or is damaged, other components can continue to function. Third, the failure of a component in the main engine support sub-system will cause all components to fail to operate, resulting in the failure of the main engine support system.

In this study, the failure points were assessed by calculating the value of the Risk Priority Number (RPN), as presented in Table 2. Critical components are identified using the RPN value and cumulative frequency. That is, the component in a system that, if it fails, increases the likelihood of the entire system failing. As a result, the criticality of the component is determined by which components, if failed, will have an impact on the sub-system. The greater the RPN value and the lower the cumulative frequency value, the greater the component's criticality value, allowing for more frequent maintenance than other components. Furthermore, following the evaluation of the RPN for each component, the criticality analysis (CA) method is used, which employs a criticality matrix. The criticality matrix's function is to prioritize failure modes based on their severity and frequency of occurrence. The priority of the failure mode must first be determined when selecting a failure mode. To determine the priority of this failure, a Pareto diagram is required. This Pareto diagram's function is to sort the failure rate from largest to smallest, with the largest on the right side of the diagram and the smallest on the left, as illustrated in Figure 4. Ultimately, the components of the support system with a high criticality level are identified using the RPN value and the Pareto diagram, as resulted in Table 3. To conclude, according to the findings of the FMECA appraisal, the cooler, sea chest filter, and filter were the most problematic components. These are components with a large RPN value. This is because the component has been damaged, causing the main engine to fail spectacularly. Failure of a component with a limited RPN value has no direct effect on the main engine. Prevention can be carried out by taking into account the risk of failure, such as regular maintenance actions. The maintenance intervals are chosen to minimize maintenance costs. This maintenance consideration employs the minimum reliability scenario, which will be determined by the system dynamics model in the following section.

Table 2. RPN Compilation of Main Machine Support System

No	Component	Failure	Severity	Occurence	Detection	RPN
1	Filter	Dirt accumulation	4	9	1	14
2	Transfer Pump 1	Dirt accumulation	3	3	3	9
3	Transfer Pump 2	Dirt accumulation	3	3	3	9
4	OWS	Dirt accumulation	3	3	3	9
5	Feed Pump 1	Impeller replacement	3	3	1	7
6	Feed Pump 2	Impeller replacement	3	3	1	7
7	FW Pump 1	Impeller replacement	3	3	1	7
8	FW Pump 2	Impeller replacement	3	3	1	7
9	Cooler	Dirty coolers	5	7	3	15
10	Sea Chest Filter	Dirty suction filter	4	9	1	14
11	SW Pump 1	Imepeller replacement	3	3	1	7
12	SW Pump 2	Imepeller replacement	3	3	1	7

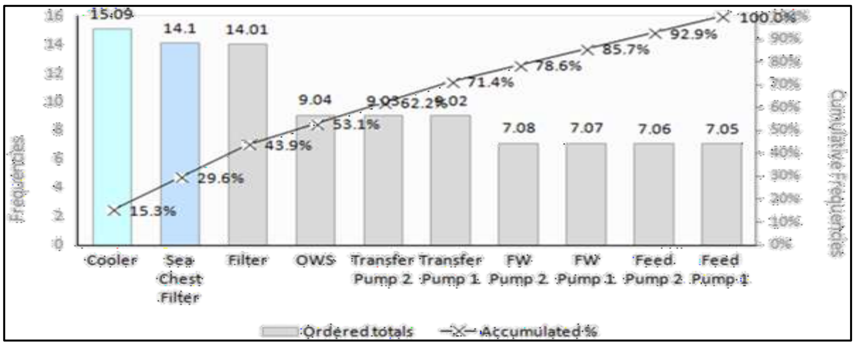

Fig.4. Pareto Diagram of the Main Engine Support System

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Table 3. FMECA Report for Main Engine Support System Components

No.	Component Selection	Failure Detection	Sev.	Occ.	Det.	RPN
1	Filter	Dirt Accumulation	4	9	1	14
2	Cooler	Dirty Coolers	5	7	3	15
3	Sea Chest Filter	Dirty Suction Filter	4	9	1	14

3.2 System Dynamics Modeling

The system dynamics model is adjusted to the FMECA to work effectively for critical components. The goal of modeling planning is to generate recommendations for maintenance time for each component of the main engine support system, as well as total cost based on docking costs, spare parts, and KMP. Kormomolin crews salary. The PowerSim scheme is used for modeling, and there is only one model that includes all the analyzed data, as depicted in Figure 5. Based on the reliability value enumerated, a value of 0.30 is used to evaluate maintenance since the smallest maintenance costs are gained at a reliability index of 0.55. This category encompasses all supporting systems for the main engine of KMP. Kormomolin vessel will be examined.

Following the completion of the running process, the simulation results from the system dynamics model will be displayed, including the value of avability, MTTF (mean time to failure), reliability, and recommendation cost, as presented in Figure 6, Figure 7, Figure 8, and Figure 9. Scenarios with minimum reliability of 0.20-0.95 were created to simulate the relationship between reliability, availability, and cost. Following the creation of the model, the total maintenance cost and reliability of the main engine support system for a period of five years were determined. The failure rate obtained from primary data in the form of filter, cooler, and sea chest filter maintenance is used to calculate MTTF. Meanwhile, various maintenance actions are performed on the components in order to calculate the amount of maintenance costs that will be incurred by the company. The average working hour cost of the ship's crew is IDR 7,500,000 per 30 working days, according to field loss data. So the crew earns around IDR 31,250 per hour of work. Meanwhile, maintenance cost modeling is being developed to determine how much maintenance costs ship owners will incur over the next year. The cost calculations are simulated for a year based on the ship's docking survey schedule. Entering the value of maintenance costs per each damaged component in the system and adding the cost of additional crew wages during maintenance activity implementation.

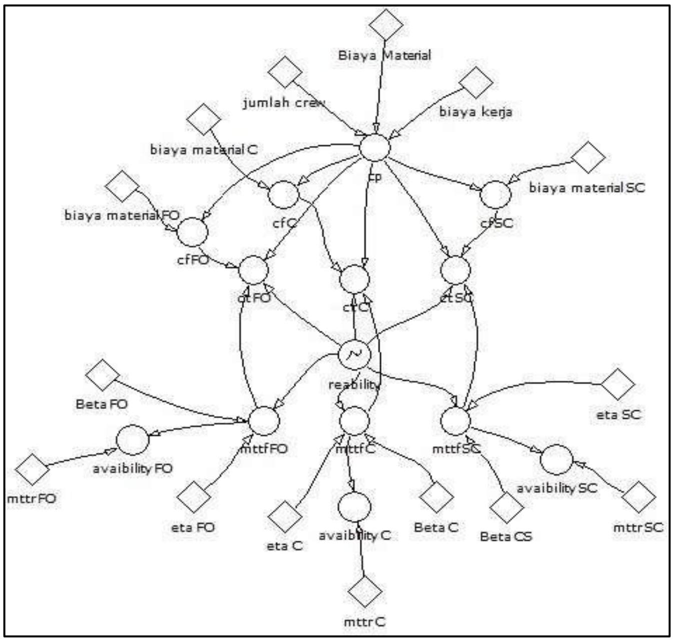

Fig.5. Sketch of PowerSim Scheme for Modeling the Main Engine Support System

Beside that, the simulation outcomes also provide recommendations for schedules and maintenance costs in Table 4 and Table 5. Each component has a different maintenance interval because of its different failure rate. The optimum maintenance cost for 5 years was obtained after a

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simulation scheme. The term of scheduled routine maintenance still refers to the docking schedule for the year. In other words, it generates a simulated picture of the maintenance schedule over a year if the ship operates normally twice a day and takes two days off each month.

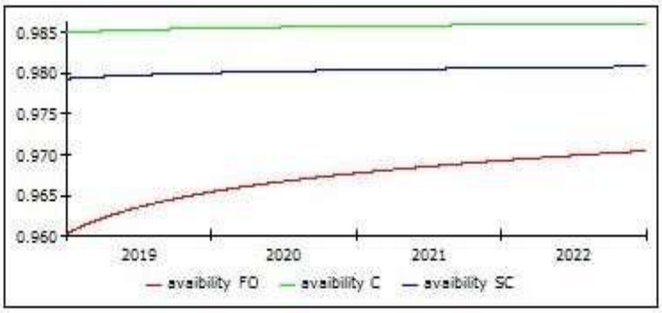

Fig.6. Availability of Main Engine Support System

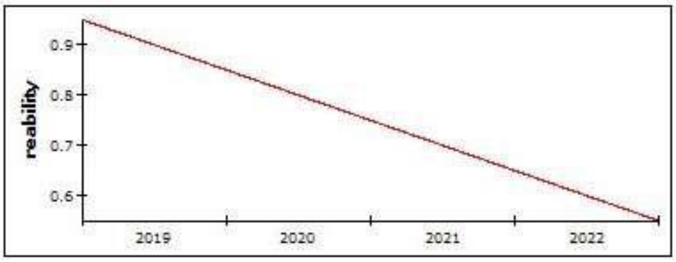

Fig.7. Reability of Main Engine Support System

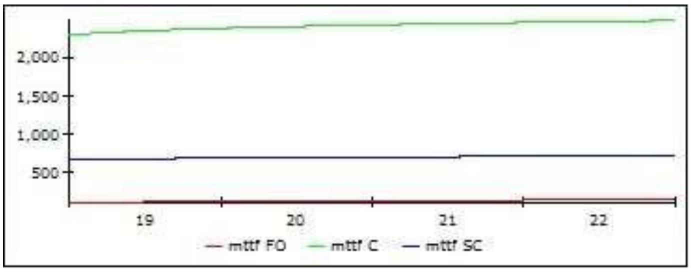

Fig.8. MTTF Main Engine Support System

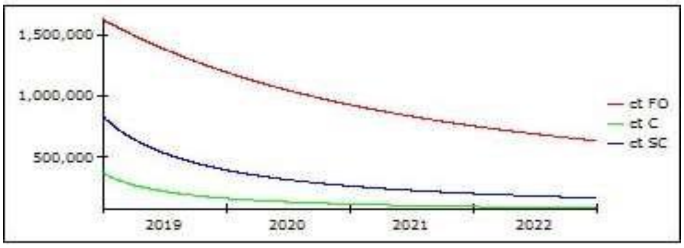

Fig.9. Total Cost of Main Engine Support System

Table 4. Recommendations for Optimal Treatment Time

Components	Treatment time (Hours)	Maintenance Scheduling (Date)
F.O. filters	151	January 31, February 28, March 31, April 30, May 31, June 30, July 31, August 31, September 30, October 31, November 30, and December 31,
Cooler	2481	February 28, May 30, August 31, and November 31
Sea Chest Filter	722	February 28, April 30, June 30, August 31, October 31,

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3.2 Comparasion of Existing and Recommended Costs

After determining the cost and time required to maintain each component in each sub- system supporting the main engine, recommendations are made for existing costs as well as recommendations based on optimal reliability values. Based on the data obtained, the company performs preventive maintenance for the fuel system at a cost of IDR 75,169,300 and preventive maintenance for the cooling system at a cost of IDR 50,506,000. Thus, the company's annual cost is IDR 125,675,300. However, each component has a different maintenance interval due to its different failure rate. Following the simulation, the optimum maintenance cost for 5 years is determined. However, given that maintenance planning is only done every four years, the maintenance and repair costs are as follows. It's just that the annual docking schedule is still referenced in the scheduled routine maintenance.

According to the fule system simulation results, the optimal cost for each maintenance activity is IDR 630,756. With preventive maintenance intervals every 151 hours (6 days), the number of treatments in a year is 12 times, thus the annual maintenance cost is IDR 7.569.072. The cost of maintenance losses is IDR 6,600,000. At last, the total annual maintenance cost becomes IDR 14,169,072. The optimal cost for each maintenance activity, following the cooler results, is IDR 78,377. With routine maintenance periods each 2481 hours (103 days), the number of treatments in one year is 4 times/month, therefore the maintenance cost in one year is IDR 313.508. The cost of losses suffered during maintenance is IDR 16,000,000. Finally, the total annual maintenance cost is IDR 16,313,508. Depending on the sea chest filter results, the optimal cost for each scheduled maintenance is IDR 161,192. With preventive maintenance intervals every 722 hours (30 days), the maintenance cost in one year is IDR 967,152. The cost of maintenance losses is IDR 10,200,000. Ultimately, the total annual maintenance cost will be IDR 11,167,152.

The actual costs in order of the company and the collected dynamics modeling process are determined. The rate of savings can then be derived by attributing distribution costs among both companies and the dynamics modeling method. By comparing the distribution costs between the company and the dynamic modeling method, it is then possible to calculate the percentage of savings from the calculation of the real distribution costs of the company and the obtained distribution costs. Taking into account the findings, the percentage of annual fuel filter maintenance cost savings considered is 81% of the previous maintenance cost. Furthermore, the expected savings in annual maintenance costs for sea chest filters and coolers are 46% of the latest maintenance costs.

4. Conclusions

This work computationally highlights the reliability of the main engine support system of the KMP. Kormomolin vessel. The FMECA, system dynamics, and maintenance costs are explored. It is sufficient to obtain the following conclusion:

1. According to the findings of FMECA, the critical components in the fuel system are filters, while the critical components in the cooling system are coolers and sea chest filters.
2. The determination of the maintenance schedule for each sub-system on the ship's main engine support system, among other things, is based on the results of the analysis using system dynamics method. The results show that the fuel oil filter is serviced every 151 hours, the cooler is serviced every 2481 hours, and the sea chest is serviced every 2481 hours. The filter is changed every 722 hours.
3. The total cost of maintenance for the ship's main engine support system after simulating the system dynamics modeling for a year. The initial cost of the fuel system is IDR 75,169,300, while the recommended cost is IDR 14,169,072, representing 81% savings. The initial cost of the cooling system is IDR 50,506,000, and the recommendation fee is IDR 27,480,660, yielding 46% savings.

To increase the reliability of each component, KMP Kormomolin vessel should conduct periodic maintenance and pay special attention to components with high probability values and criticality levels. Furthermore, the findings of this study should be employed to establish a better maintenance management system for the KMP Kormomolin main engine support system.

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